Towards an active anechoic room

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ESAA Project - Toward an active anechoic room

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Abstract This is a presentation of some works in active control. Most of them were conducted by members of the LMA. We will show how these previous works have led to the project which is called "Active anechoic room" and is now carried out in the laboratory. The final aim of this project is to develop an active control system in order to increase sound absorption in the LMA anechoic room at low frequencies. Indeed, the characteristics of an anechoic room is to reduce the echoes coming from the walls in a very large frequency range. In the middle and high frequency range, this is very well achieved by covering the walls with absorbing materials. At very low frequencies (below 100Hz for example), this is more difficult but the active control systems are quite efficient at these frequencies and can be used as an additional tool to improve the acoustic performances of the passive system that is the coating on the walls. Apart from its practical applications, the study addresses more general questions related to sound synthesis and representations of sound fields and sources.

1 Introduction

For several tens of years the LMA has been contributing to a large amount of works on active sound control and the most recent studies concern both active control and sound synthesis (see [1, 2, 3] for example). The expertise gathered from these works is now used to carry out a project called "Active anechoic room" described in the abstract. The practical application of this project is to define and realise an experimental set-up in order to study acoustics radiation and propagation problems in a low frequency range and at short distances with a high accuracy. The general idea is therefore to add an active sound system to the existing passive system in the anechoic room.

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2 Some LMA previous works in active control

A choice of three examples of works conducted at LMA is presented. The first one, the most classical, consists in minimising the sound field inside a volume. The original sound field is emitted by a source called primary source located outside the volume. The sound reduction is achieved by using secondary sources located at the boundary of the volume. These sources are driven from sound pressure measurements on microphones located inside the volume and by using specific algorithms such as LMS. It is well-known that this kind of system provides good results at low frequencies.

The second example is a sound synthesis example. The aim is to create a sound field with given characteristics in a volume inside a room. The sources are located on the walls of the room and a set of microphones is located on the boundary of the volume. A Green's formula is used to relate the sound pressure measured on the microphones to the sound pressure at any point in the volume. Then the system consists in driving the sources from measurements on the microphones. An experiment was carried out in a 2.7x1.7x2 m^3 room, in the 100-400 Hz frequency band.

In the third example, the aim is to minimise the sound pressure diffracted by an object in a room (see [1] and Fig. 1). The primary source is a loudspeaker located in a corner. The goal is that the sound pressure at the exterior microphones should be as close as possible to the incident pressure, that is the sound pressure that would exist in the room with no object. The total sound pressure is measured by interior microphones located around the object. The secondary sources are driven from the measurements obtained on these interior microphones. An integral equation is used to relate the total pressure on the exterior microphones to the total pressure on the interior microphones. The diffracted pressure is deduced from two series of measurements, with and without the object. An experiment was conducted in an anechoic room with the geometry shown in Fig. 1 at 280 Hz with an object of volume 1.6x0.9x0.5 m^3.

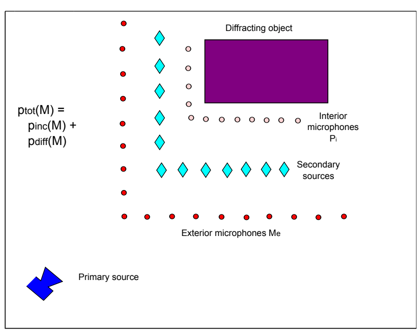

Fig.1 - Active control of the sound pressure diffracted by an object

3 The active anechoic room project

The aim of this project is to minimise the echoes coming from the walls of an anechoic room in order to increase the absorption efficiency of the coating (see Fig. 2) at a low frequency range. The source S is the primary source that we want to characterise accurately. The active control system is based on an array of loudspeakers located along the walls and driven by using pressure measurements on an array of microphones P_i located around the source. This is somewhat similar to the case of diffraction by an object described in the previous section. However, here, there is no direct way to assess the diffracted pressure. Therefore, this problem includes two steps : 1/ to estimate the diffracted pressure at point M ; 2/ to reduce the level of this diffracted pressure. Here, we only consider the first step, that is to develop a method in order to estimate the echoes arriving at point M.

Such a problem is modeled by using integral representations in order to obtain a relation between the total field measured on the microphones $p_{tot}(P_i)$ and the diffracted field at the observation point M $p_{dif}(M)$. At this stage, a monochromatic source is assumed, with an angular frequency ω. By using Green's formulas, it is possible to obtain the following representation :

$$p_{dif}(M) = (\mathscr{H}[p_{tot}])(M) \text{ pour } M \in \Omega \tag{1}$$

where the operator $\mathscr{H}$ is an integral operator over the surface of the array of microphones which represents the exterior boundary of the volume Ω. It can be shown that this operator exists and is uniquely defined but cannot be obtained explicitly, except in very simple cases. It must be remarked that it depends on the point M and the microphones P_i but does not depend on the source. This leads to a two-step method. A first set of sources is used to identify the operator by minimising the expression $|p_{dif} - \mathscr{H} p_{tot}|$. This is done by using a SVD method. Once a numerical approximation of $\mathscr{H}$ is obtained, the relation (1) can be used to compute the diffracted pressure for any other source.

The presentation will show some theoretical and numerical aspects of the study. From a numerical point of view, the effect of various parameters must be studied carefully, such as the number and positions of sources and microphones, the impedance on the walls and the frequency, etc. Because the problem solved is an inverse, ill-posed problem, the quality of the numerical results tightly depends on the way the physical characteristics of the problem and the final objective of sound reduction are taken into account.

4 Two examples of industrial applications

Two kinds of industrial applications of active sound control are finally described. For the first one, an active control system was designed in order to reduce the sound levels emitted by an electrical transformer. This system was first realised three years

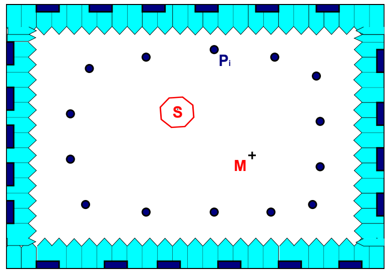

Fig. 2 - Active control of the sound pressure in an anechoic room

ago in an area of a Swiss city for the ATQ company and is still in use. The emitted signals are measured on a continuous time basis at several distances from the transformer. The second example is more similar to a sound synthesis experiment. It was conducted for Thales Alenia Space. The aim was to produce a diffuse sound field in a room used to test satellite responses to severe conditions (see Fig. 3). The sources are loudspeakers located along the walls which are driven at low frequency by an active control system.

Fig. 3 - Sound synthesis in a satellite testing room

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